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Forest harvesting impacts on forested wetland forest ecosystem function – biogeochemical cycling

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Forest Harvesting Impacts on Forested Wetland Ecosystem Function – Biogeochemical Cycling

by

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ABSTRACT

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Key Words: biogeochemical cycles, carbon, forest harvesting, forest wetland, nitrogen, phosphorus, wetland function

The wetland ecosystem is located at the interface of the atmospheric, terrestrial and water system. It is one of the most biologically diverse ecological landscapes on earth and one of the most important environments for mankind. It also called "kidney" of the landscape because it can purify water that passed through the wetland. Forested wetland is one of the classifications of wetland, also defined as swamp, dominated by trees and plays a significant role in timber supply for forestry business. Forest harvesting such as clear-cut, is the most common silvicultural method used in forest regeneration. However, it can alter the functions of the forested wetland ecosystems –biogeochemical cycling. Data have been collected from several literature reviews and explores how forest harvesting impacts carbon, phosphorus, nitrogen, calcium and potassium cycles. After data analysis, the five nutrients were reduced after forest harvesting, but the changes in nitrogen content were considered minimal. Harvesting has a direct impact on biogeochemical cycles and it is important to protect the wetlands by maintaining the levels of nutrients and quality of environment and ecosystem.

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INTRODUCTION

Wetlands are essential for wildlife habitation, regulation of hydrology, and sequestration of carbon. Forest harvesting has the potential of altering the natural processes of biogeochemical cycles hence several unwanted changes in the ecosystem (Jiang, 2016). Long-term and continuous human activities are to blame for the loss of Forested wetlands across the world at alarming rates. Today, it is reported that the wetlands in the world have been reduced between 54% and 57% due to loss of biogeochemical cycles (Davidson, 2014).

Forests ecosystem in the wetland sections of forests is a very crucial part for the biodiversity and the natural ecosystem. Forests form the most important sources of rivers and lakes that drain into oceans and seas. In South America, for example, the Amazon rainforest is an important source of rivers such as Missouri and Mississippi rivers in North America, which are the longest and widest rivers in the world. In the same context, forests are rich sources of hardwood trees that are used for various human activities. Trees such as oak (*Quercus*), pine (*Pinus*), and other indigenous trees are needed for construction and making of furniture, among other uses.

This paper focuses on the wetlands and forests, mostly in North America and parts of Canada. Wetlands are located in different parts of the forests and are home to animals and plants, naturally occurring economic resources, and wood. For this reason, the topic of wetlands has become a very important subject of interest to environmentalists and the government. The arrangements of rainforests, especially the Amazon, suggest that there is a link between forest covers, wetlands, and other bordering lands and water masses (Conservation Foundation, 1988)

Human activities have become a menace to the very existence of the wetlands and forests cover. According to research and surveys, more than half of the wetlands in North America have been wiped out due to forest harvesting (Jiang, 2016). This thesis seeks to look into the effects of forest harvesting on wetlands ecosystem functioning. The thesis will involve a case study to understand whether there is a relationship between forest harvesting and the biogeochemical functioning of the wetlands. The biggest problem and gap is the limited information and data to draw policy for forest management and conserving the wetlands. The importance of wetlands to neighboring water masses, habitats, carbon, phosphorus, and nitrate cycling, hydrology, and overall biodiversity cannot be underestimated and therefore necessitates the need to assess the impact of forest harvesting on wetlands.

LITERATURE REVIEW

Wetland ecosystems represent places where organisms live and interact when water meets land. The interaction between various animals provides an important environment and resources that are used to meet their needed success (Remm *et al.*, 2013). Three main functions and values of wetlands include the hydrology regulation, biogeochemical cycling and wildlife habitat, which indicate that altering wetland functions will result in huge shifts to the environment (Wigley *et al*., 1994). Wetlands are important because they retain enormous amounts of water and essential nutrients cycle among the wetland, atmosphere and soils. Forest harvesting has severe impacts on wetland ecosystem function because it will alter the changes of water table, the content and the process of the nutrients and environmental conditions of wildlife.

Wetlands cover about 25% of world's land mass. In Canada, it is estimated that there are 1.5 km^2 of wetlands which cover 16% of Canada's land mass (Table 1). Thirty-seven wetlands in Canada, covering an area of about 131,000 km^2 have been established to be of international importance (The Canadian Encyclopedia, 2020). The wetlands in Canada are home to more than 600 species of plants, animals and insects. Wetlands are essential in providing a habitat to these organisms. Wetlands are also essential in preventing flooding, storing groundwater, filtering toxins and limiting erosion. Therefore, they help to protect the surrounding environments from various harmful outcomes significantly.

Table 1: Percentage of Area Covered by Wetlands in Canada Provinces (Kolka *et al.,* 2018).

	Province	**Percentage of province**
1	Alberta	20%
2	British Columbia	5%
3	Manitoba	10%
4	New Brunswick	5%
5	Newfoundland and Labrador	10%
6	Nova Scotia	6.90%
7	Ontario	22-29%
8	Prince Edward Island	25%
9	Quebec	10%
10	Saskatchewan.	11%

Benefits of Wetlands

Wetland ecosystem provides several benefits to water regulation, essential nutrients cycles, wildlife habitat and biodiversity. The wetlands play an important role in improving and regulating water quality because heavy metals might be poisonous to aquatic life (Steven & Lowrance, 2011). Wetlands provide suitable environmental conditions for both endangered and threatened animals and plants. Forest harvesting affects the wetlands because they destroy important natural resources that promote wildlife and marine lives (Tousignant *et al.*, 2010). Table 2 shows the changes in US wetlands (conterminous = 48 states on the continent) over the years from 1780 and 1997.

Table 2: Changes in wetlands over the years from 1780 and 1997

Time Period	Geographic extent of estimate	Total wetland (acres)	Forested wetland
1780	Conterminous U.S.	221,000,000	No estimate
1980	Conterminous U.S.	104,000,000	No estimate
% change		47%	
1950	Conterminous U.S.	54,257,000	38,000,000
1970	Conterminous U.S.	46,500,000	32,000,000
% change		15%	16%
1970	Conterminous U.S.	51,200,000	35,300,000
1980	Conterminous U.S.	48,900,000	33,004,000
% change		5%	7%
1986	Conterminous U.S.	106,135,700	51,929,600
1997	Conterminous U.S.	105,500,000	50,728,500
% change		1%	3%
1986	Conterminous U.S.	49,883,779	33,735,000
1997	Conterminous U.S.	49,585,000	32,643,000
% change		1%	3%

The continued harvesting of forests in the US bears a negative effect of wetlands within the region. Most wetlands in the South region of the nation occur on poorly drained mineral or organic soils in lowland areas. Therefore, they rely more on the presence of forests that act as water catchment areas. The presence of forests is important in ensuring that the soils contain the desired amounts of water, which would ensure the continued sustainability of the wetlands. Therefore, the destruction of forests, often as a result of development, means that wetlands are also put at a high level of jeopardy (Cohen *et al.*, 2016).

Forests are also important in adding the necessary nutrients to soils. The soils, therefore, attain the ease of supporting wetlands effectively, especially, with respect to the various plants, which are found on them. It is through these processes that forests manage to act as a habitat for various organisms. These organisms attain the ease of surviving within the wetlands, especially, if they are of diverse types and numbers. They manage to form a specific level of development that are critical in ensuring the continued support of various organisms. Much value, therefore, lies in ensuring that there is the continued availability of various nutrients that are crucial in improving upon the quality of wetlands. Through the process, it is possible for them to be sustained for long and create the desirable levels of biodiversity.

The term biogeochemical cycle refers to the recycling of inorganic matter (Boundless), which occurs in the earth's ecosystem between the living and the non-living organisms. The ecosystem contains several significant elements that make it possible for the cycles to happen, and these elements include; carbon, phosphorous, nitrogen, hydrogen, Sulfur, and oxygen. Through geologic processes such as erosion and weathering, these elements are involved in cycles that make them useful to the earth's ecosystem (Orians, Charlson & Butcher., 2014). Each of the six elements that have been mentioned plays a critical role in ensuring the stability of the ecosystem. To begin with, Hydrogen and Oxygen are the constituent elements of water, which is a vital component of life. All six elements may exist in the atmosphere for an extended period. Furthermore, carbon is an element found in all the organic molecules that are also constituent of other vital components to life. Nitrogen is also essential because it is found in proteins and nucleic acids. Phosphorous and sulfur make up biological membranes and proteins, respectively.

The usefulness of these elements to the ecosystem is made possible by various interconnected biogeochemical cycles. The cycles, which are all unique, make it possible for the living and non-living environment to interact and hence coexist. The cycles ensure the movement of elements through the earth's atmosphere and therefore enhancing the lives of living organisms by making them interdependent while also making the non-living things useful. Through these cycles, the various processes of life, such as photosynthesis, are made possible hence providing food to billions of living creatures.

The Water Cycle

Water is perhaps the most important natural component of life, because over half of the bodies of almost all living organisms, including human beings, are made up of water. Living organisms, therefore, need water for their survival, and they are always looking for the commodity. However, while the majority of the earth’s surface is made up of water, only about 1% of the water is readily available for consumption. The water cycle helps to supply living organisms with fresh water by assisting the transformation of the salty water into fresh water that is usable. The water cycle is aided by the sun, which heats the salty water in the ocean, causing it to evaporate. Once the water evaporates, it forms clouds that are later heated and cause rain (Cech, 2010). The rain pours in the form of fresh water that is used by plants and also absorbed by the earth's surface into the ground. The absorbed water can be harvested for consumption by human beings. In addition to this, some of the water from the rain forms rivers, streams, and other freshwater bodies that provide water that is fit for consumption. Water is vital because it is directly consumed by living organisms as well as used by plants to make food that is also used by living organisms for survival (Jakab, 2008). In addition to this, the water cycle helps to drive other cycles because when water runs off the earth's surface, it carries with it other important elements such as carbon, phosphorous *etc*. and hence aids their movement in the earth's atmosphere.

The Carbon Cycle

Carbon is known to be an essential element both to human beings and to plants. To human beings, the element is economically utilized for the production of fuels that help to run day-to-day activities. Carbon also combines with oxygen gas to form the gas CO_2, which is an essential requirement for photosynthesis in plants, a process that enables the plants to produce food that is important for both their growth and also consumption by human beings (Grace, 2011).

The carbon cycle can be broken down into two main sub-cycles. The first sub-cycle explains the exchange of carbon among the living organisms while the other sub-cycle is concerned with the geologic processes that enable the long-term cycling of carbon. However, while the two sub-cycles may seem different, they are interconnected. For instance, human beings and plants share carbon through the air by natural processes such as respiration (Ikeda, Tajika & Tada, 2002). When these organisms die, they are absorbed into the ground where they decompose, and they help in the formation of carbon through the geological processes.

The Nitrogen Cycle

Nitrogen is one of the most critical elements in living organisms. The Nitrogen atoms aid in the formation of the DNA and proteins of living organisms. In the atmosphere, nitrogen occurs in the form of the N_2 compound, which is a gas. Nitrogen forms the most significant percentage of air in the atmosphere compared to the other constituent gases (Slade, 2007). In addition, nitrogen plays an important role in the de-nitrification of wetlands, which entails converting nitrogen into nitrates in a few days. The loss of nitrogen from the wet soil results in alkaline soil that causes high volatilization where significant amounts of nitrogen are lost through ammonia gas. The nitrogen cycle is fueled by bacteria, which convert nitrogen from its gaseous form into other forms such as ammonia and other biological forms that are more useful to the ecosystem (Virtanen, 1952). The process of this conversion through the bacteria is called nitrogen fixation.

Through nitrogen fixation, bacteria and other microorganisms convert the atmospheric nitrogen to the more useful ammonia that is used by plants and also is an important part of organic molecules (Schlesinge *et al.*, 2006). When animals consume plants in the form of food, nitrogen is passed into the bodies of the animals where it is broken down into various components useful to the bodies of these organisms, while some of it is excreted as waste in the form of urea. On the other hand, forest-harvesting causes increased temperatures in the soil thus increasing the production of ammonium nitrate (Tiner, 2013).

The Phosphorous Cycle

Phosphorous is another critical element in the ecosystem because it is a component of the DNA of human beings and other living organisms. It has lower mobility rates in most soils compared to nitrogen but it cannot be lost in gaseous forms. The phosphorus cycle is often labeled a slow cycle because its effects take thousands of years to manifest (White & Dyhrman, 2013).

Phosphorous occurs in the form of phosphate ions in nature and its compounds located in sedimentary rocks. As these rocks breakdown due to natural processes, the phosphorous is slowly absorbed into water and the soils that surround these rocks (Delaney, 1998). From the soils and water, plants take up the phosphate compounds, which are then transferred to animals as they consume the plants. When the plants and animals excrete or eventually die, the phosphates ions and compounds are returned to the soil, and the cycle continues.

In the marine ecosystem, the waste from marine life and even the remains from the death of aquatic life also release phosphorus into the water bodies, which over a long period form other sedimentary rocks that help the cycle to continue (Sohrt, Lang & Weiler, 2017). The sedimentary rocks may also be moved from the ocean to the land through natural geological processes, but it is a process that could take tens to hundreds of thousands of years. Forest harvesting may cause significant changes in phosphorous, because the harvest can cause the rise of water tables.

These water tables may then increase the production of phosphorous through chemical decompositions. During floods and other water run off, the excess phosphorous is swept down to watersheds thus increasing water acidity (Camacho-valdez *et al.*, 2014).

The Sulfur Cycle

The sulfur cycle is also another critical element in the ecosystem. In the living organisms, sulfur is a constituent element of the amino acids that help in the formation of proteins.

One of the ways that sulfur is released to the atmosphere is through the decomposition of organic molecules. A second way is through volcanic action, and the venting of steam from geothermal power production. A third is through human activities such as the burning of fossil fuels (Sievert, Kiene & Schulz-Vogt, 2007). In the atmosphere, sulfur occurs in the form of sulfur dioxide (SO_2), which gets into the atmosphere via various methods (Farquhar, 2000). In addition to this, Sulfur is also deposited on the earth's surface through various ways such as falling directly from the atmosphere, weathering of rocks, precipitation, and even the venting of steam from geothermal power plants. The steam vented from the power plants contains amounts of hydrogen sulfide (H_2S) gas from where sulfur, deposited on the earth's surface, is found.

The Calcium Cycle

Human activities are identified as the topmost aspect that leads to the over-concentration of nutrients in wetlands. One of the main aspects of human activities that lead to the concentration of calcium in the respective regions includes forest harvesting where the leaves and other calcium-containing components fall and decompose in the soil. These lead to a concentration that could be detrimental to the general state of the wetlands, including its ability to enhance survival for the inhabiting organisms (Herbert et al., 2015).

The initial phase of the calcium cycle begins after the leaves, branches, and calcium-containing components of the harvested trees fall into the wetlands. Upon decomposition, the fallen components decompose and emit calcium in the form of calcium silicate and calcium carbonate. It is also relevant to identify that the forest harvesting process leads to loosening of the rock structures, which emits and leads to high calcium concentration at the groundwater in wetlands. Through the physical and chemical processes, Calcium dissolves in the wetland waters where its ions combine with Magnesium ions since they share the same ionic charge. This also enables the calcium ions to substitute with Magnesium in its attachment to carbonates. With this, the difference between the dissolved calcium and the calcium carbonates includes their concentration of Carbon Dioxide (Kadlec & Reddy, 2001).

The solubility of the eventual elements leads to extreme concentration in the wetlands. The concept of solubility, especially in the wetlands, allows for the concentration of Calcium to remain higher in the lower sections of the wetlands as compared to the top levels. Most of the forest plants consume calcium in a soluble and ionic form where it enables them to access phosphorous and other micronutrients. After the absorption, the inevitable death of plants as well as falls of plant sections after harvesting leads to the return of calcium to the wetlands and the soil, where it can then be washed down to the wetlands.

The Potassium Cycle

Following the adverse fall of tree components, including seeds, leaves, and barks, after harvesting of forests, the potassium components enter the soil after the decomposition process. The potassium-containing components that fall directly to the water bodies convert to potassium ion that concentrates directly the wetlands. However, a large percentage of potassium that concentrates the ground levels in wetlands always enters through leaching and erosion. Notably, potassium is not chemically bound to other elements through the organic combinations. This means that potassium can easily be released in the initial phases of decomposition. After decomposition, potassium in the soil is stored in a soluble ionic form where it can easily be absorbed in the soil water or held or sometimes in a soluble form (Tripler et al., 2006). The potassium enters the groundwater through the exchangeable and the non-exchangeable forms.

The groundwater then enters the wetlands through leakages and spring flow. A large percentage of the potassium that was leached to the soil enters the wetlands through precipitations and water inflow. The potassium dissolves into the ground section of the wetlands through reactions with other elements including calcium, chlorine, and hydrogen (Mori et al., 2018). The reaction leads to the formation of elements such as potassium chlorides, potassium nitrates, and potassium sulfate. The solutions alter the ionic state of potassium to one that is easily absorbed in the soil and plants as minerals. With this, the soluble potassium form is easily absorbed by plants where the cycle happens upon the harvesting of fully grown and mature trees

Organic Matter Decomposition

Organic matter in wetlands is composed of high molecular weight compounds and small molecular weight compounds that may be dissolved in the soil solution. Dissolved organic matter has proteins, polysaccharides, amino acids and other compounds of unknown structure (Batzer & Sharitz, 2014). Heterotrophic bacteria utilize dissolved organic matter by hydrolyzing complex compounds using extracellular enzymes.

Microbial biomass in the wetland aquatic environment plays a critical role in transforming and in processes such as organic matter degradation, microbial respiration, and enzyme production. Hydrolysis limits organic matter decomposition rates in wetland environments.

Organic matter and microbial biomass degradation play a critical role in nutrient regeneration for enhancing increased success and productivity. Forest harvesting causes disturbances and subsequent problems such as drainage, eutrophication, and concentration of heavy metal toxicity that negatively influences decomposition (Camacho-valdez *et al.*, 2014). High metal concentrations, such as mercury toxicity,is a major problem for organic matter decomposition and soil regeneration.

Sedimentation

Vegetation changes usually result in excessive sedimentation that drives serious biogeochemical changes that include changes in decomposition as well as the production of minerals (Chidumayo & Gumbo, 2013). Forest harvesting results in massive foliar litter fall on the ground, and can be absorbed by the microorganism, and after the decomposition of microorganisms, the nutrients contents in the soils will increase. Forest harvesting has devastating impacts on the sedimentation process as well as the accumulation of nutrients in a wetland that affects operations and ecosystems in forested wetlands (Camacho-valdez *et al*., 2014).

METHODS AND MATERIALS

To derive a meaningful correlation between the forest harvesting and forested wetland ecosystems, specific aspects of harvesting and wetland indicators need to be taken into account. It is the purpose of this thesis to study some of the methods of harvesting of various types of species of trees from specific forests and evaluating the impact they will have on the components of the biochemical cycle including carbon, calcium, potassium, nitrogen and phosphorus.

In order to analyze impacts of the forest harvesting on wetland function, this thesis is purely based on the studies of a Michigan wetland (Figure 1; red star), which integrates and summarizes academic research on this topic, obtaining results through data comparison. The sample site study in the Peninsula, Michigan, is located in the area bound by the west branch River and the outlet of the west branch lake (Figure 1). The watershed of the Sturgeon River, which is located in the Michigan water basin, is a good site for the study of wetlands. Geologically, this area has limestone rocks in the underground. The vegetation cover of this area includes trees such as black spruce (*Picea mariana*), Jack Pine (*Pinus banksiana) etc.* (Trettin, Jurgensen, Mclaughlin, & Gale, 2018) Most of the area is further covered by shrubs of two types: leather leaf and Labrador tea. On the surface, the dominant vegetation is starflower, goldenrod, and bunchberry (the most conspicuous vegetation observed within this site study).

Figure 1: The position of the site study in Michigan. Source: Tes – physical Map of Michigan. http://www.freeworldmaps.net/united-states/michigan/michigan-map.jpg

Looking into the soil type which is mixed, there is Histic endoaquod, frigid, and sand, which form the Kinross soil (Ruth, 2018). The drainage of the soil is very poor, which allows the wetland vegetation to thrive. The soil goes down to up most 12.5 meters, and the top part is composed mostly of decomposed material. The amount of clay is negligible with equal acidity all through (Table 3). The water table does not go so deep, making the area wet most time of the year.

Table 3: Composition of the Kinross Soil (Trettin, Jurgensen, Mclaughlin, & Gale, 2018)

Horizon	Depth range (cm)	clay(%)	silt(%)	sand(%)	pH
E	0-20	<0.1	4.2	95.8	4.3
Bs	20-44	<0.1	1.5	98.5	4.7
BC	44-72	<0.1	1.7	98.3	5
C	72-100	<0.1	0.7	99.3	4.3

The climatic conditions of this area are favorable to the type of trees and vegetation growing here. According to (Albert, 1986) the growing period of the cover vegetation is approximately 144 days, having a rainfall of 850 mm. The average temperature of 5^{o}C. The main season is between May and September, which get a maximum temperature of 14^{o}C.

During the study, some areas that had trees were cleared using machines. The trees were transported to different locations where they were separated into different groups of fiber and fuel. They were used for paper making, building, and construction, and for fuel. Chemicals were used to spray the trenches and beds to reduce the impact of competition from other vegetation. Three sections were also cleared, with the same features, size, and chemical characteristics to be used as control experiments. The characteristics change, and any chemical, geological, and biological changes in the area were closely monitored to understand how the soil, water, and vegetation responded for 60 months. After the period was over, the results were obtained and have been represented in the tables and figures below from the sampled assessment carried out. Timber continued to be harvested as usual while monitoring the treatment and the sample study site for any changes closely.

RESULTS

Carbon Cycle

From the results and the impact of whole tree harvesting (WTH), it was established that WTH resulted in 47% (Table 2) in soil reduction barely one year after wood harvesting. The carbon was reduced 72% in forest floor and 46% in mineral soil. Carrying out intensive preparation leads to less carbon in the soil or the composition of the organic content (Morris and Pritchet, 1983); the level of organic decay was related to site preparation. According to (Trettin, 1995) moisture and temperature are important factors causing a reduction in soil. According to Table 5 and Figure 2, the total carbon removal of jack pine (*Pinus banksiana*), black spruce (*Picea mariana*) and sugar maple (*Acer saccharum*) that grow around the study site, the harvesting caused large carbon removal (14%, 23% and 14% respectively) compared to the whole tree.

Table 4: Content of Carbon it the soil after forest harvesting (Trettin *et al*., 2018)

	Carbon content (mg/ha)		
	Uncut	Whole-tree harvest	Loss(%)
Forest floor	31.4	8.9	72
Mineral soil	35.0	18.9	46
Total	66.4	35.2	47

Table 5: Total carbon removed of three species (Morrison et al. 1994)

	Total carbon removed (kg/ha)		
	Jack pine	Black spruce	Sugar maple
Stem	52900	51500	70500
whole tree	61600	68600	95700
tree harvest	71600	89000	111800

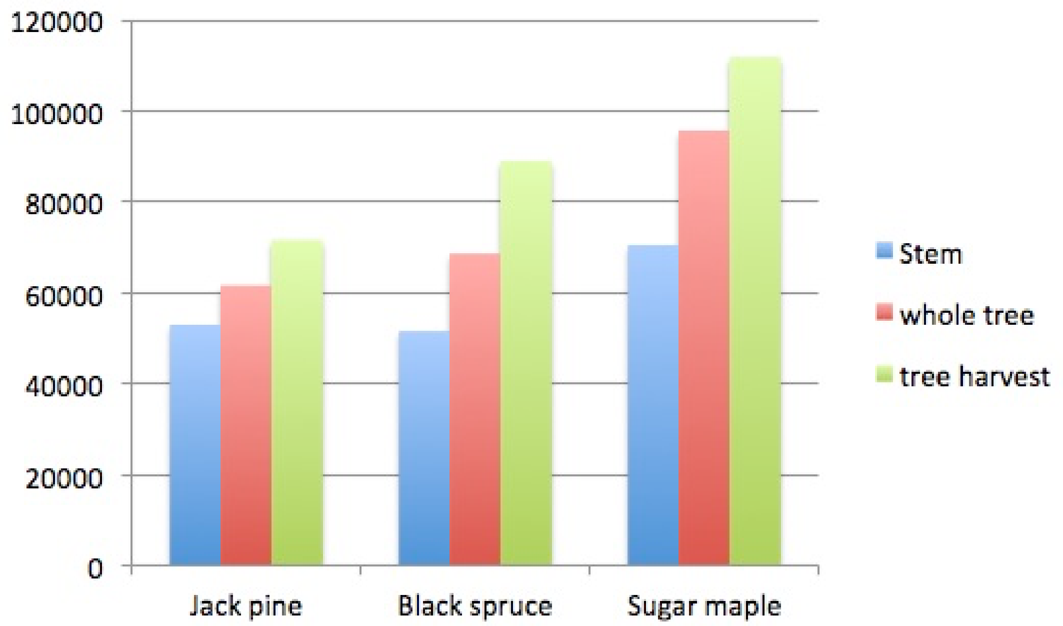

Figure 2: Total carbon removed of three species

Phosphorus Cycle

Very few studies show the changes in the loss of phosphorus after forest harvesting (Kreutweiser *et al.*, 2008; Malik and Teichert 2009). This is an important element in the soil and could be lost from harvesting trees (branches are the places that have highest phosphorus content) that cause leaching from decomposing matter. Tree felling exposes the ground to the erosion of phosphorus-enriched soils in the wetlands. The soil was discovered to be at an increasing rate after harvesting which later reduced (Prescott, 1993)

According to (Putz *et al.*, 2003; Chanasyk *et al.*, 2003), the carrying of phosphorus from the highland harvesting areas to the lowlands covered by wetlands is absorbed by sediments, which can be easily carried by a stream of water or any overflow. From data of Table 6, the phosphorus content changes with the elevation changes. According to Table 7, the P content removed approximately five times of whole tree harvest than stem harvest, but the loss of P content was only 0.03 kg/ha dissolved in stream water (Ruth, 1998)

Table 6: Phosphorus contents among different species by elevation (Ruth, 1998)

	P content (kg/ha)		
	Low	Mid	High
Sapling trees	0.43	0.47	0.18
Seedling trees	0.21	0.11	0.05
Shrub	0.32	0.28	0.38
Fern	0.1	0.11	0.42
Herbs	0.05	0.07	0.12

Table 7: P, N, K, Ca content under uncut and harvesting removal content (Ruth, 1998)

	Nutrient content in Stem(kg/ha)	Whole tree Harvest(kg/ha)	Stem Harvest(kg/ha)
P	0.31	50	6
N	0.4	445	74
K	0.48	216	40
Ca	0.51	578	107

Nitrogen Cycle

Nitrogen exists as nutrients in soils such as nitrate compounds that are made up of nitrogen and other elements. When soils are eroded downwards starting from the highland areas where harvesting has taken place, the nitrates in the wetlands are dissolved in the water and carried away. When the water table rises, the process of conversion of nitrates to nitrogen gas is accelerated. This problem is partly alleviated by the fixing of nitrogen gas from the air into nitrates by the nitrogen-fixing plants such as the alders which seem to grow very fast after the felling of trees (Murray *et al.*, 2000; Rothe *et al.*, 2002; Stednick 2008). Table 7 shows the nitrogen loss through forest harvesting has smaller changes than phosphorus. According to (Hope *et al.*, 2003), there were no changes in the level of nitrates in the soil after seven years of timber harvesting in British Columbia. However, most of the research suggests otherwise, that most of the nitrate levels lowers in wetlands (post-harvesting) in a matter of years.

Calcium and Potassium Cycles

Calcium and potassium was reduced by the treatment processes and harvesting 25 cm deep into the surface after 12 months of disturbance (Table 8). The bedded areas and trenches contained more calcium and potassium than the areas where trees were left. Bedding and WTH treatment areas showed the biggest loss in potassium due to its vulnerability to leaching.

The removal of the forest floor was the main reason for the loss of potassium. According to (Morris & Pritchett, 1983) showed the same type of change where the levels of calcium and potassium did not change much. The diminishing levels of potassium on the forest ground, according to Tew (1986) were caused by the removal of the floor through windrowing, a difference in the treatment processes used. In other areas with forested grounds and wetlands, there was little change that could be measured statistically within four years of timber harvesting after site treatment.

Table 8: Extractable elements and acidity levels after 12 months of treatment.

Elements	Acidity level (before)	Whole tree harvest	Loss (%)	Trenched	Bedded
Ca(meq)	0.27	0.24	11.11	0.32	0.31
K(meq)	0.08	0.05	37.50	0.06	0.05
AI(meq)	0.98	0.94	4.08	1.23	1.37
AC(meq)	5.39	3.7	31.35	7.5	7.41
Total N(g)	0.084	0.069	17.86	0.083	0.072

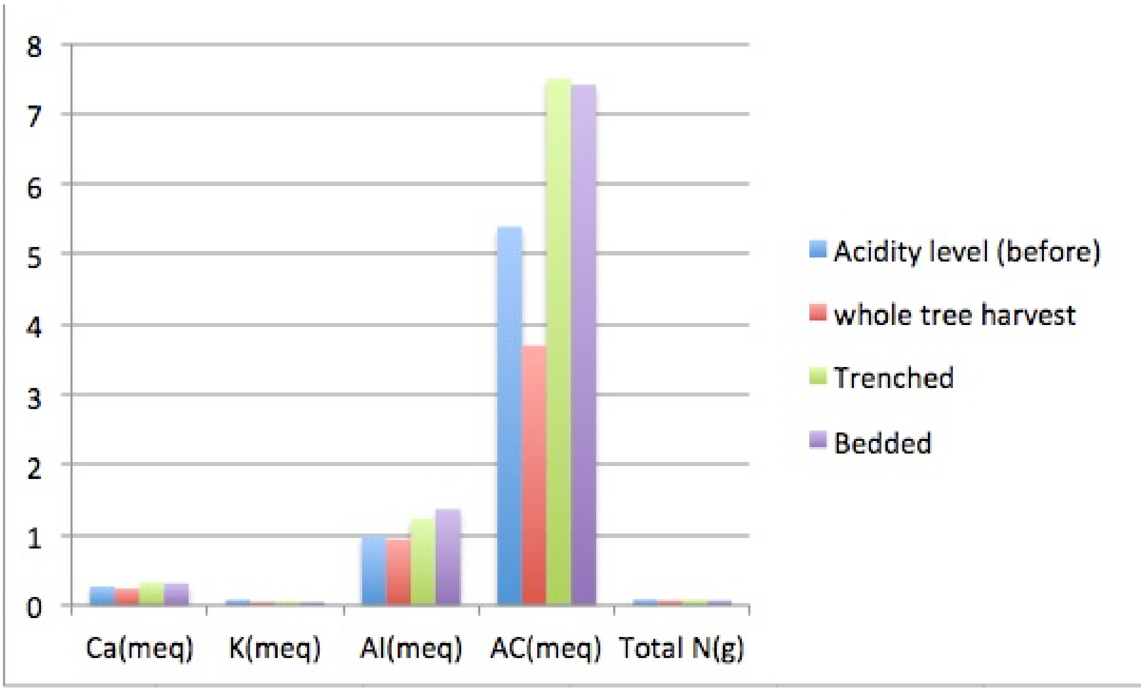

Figure 3: Extractable elements and acidity levels after 12 months of treatment.

DISCUSSION

Harvesting of timber has a direct impact on the biogeochemical cycles by changing the amount of nutrients and carbon entering into the soil, which changes the temperatures of the soil and humidity. This consequently changes the structure of the soil completely (Carignan & Steedman 2000).

The quantity of nutrients that are carried away as timber and its other contents is a relative depending on the type of plants that remain in the area where timber has fallen. The distance between the trees and the wetlands, the machines used for harvesting, the season of the year, the edibility of soil, the gradient of land and vegetation cover are all important. Harvesting has sparked several questions as to whether forests soil can still hold the same amount of nutrients after several years of continuous harvesting of trees for commercial use. When nutrients are lost in the areas bordering wetlands, the nutrients in the wetlands could also be lost. Besides, when the forests are cleared, it leaves the ground bare and prone to erosion, which could affect wetlands. The most nutrients are in tree roots and leaves which means, continuous loss of nutrients in the soil leads to change in soil physical features, chemical composition and bio productivity (Perry, 1989).

Nitrates are lost in greater and significant amounts compared to other elements (*e.g.*, phosphorus) by any overflowing water through de-nitrification (*i.e.*, the conversion of nitrates into nitrogen gas). According to (Philips, 1993) most of the hilly areas where the felling of trees has been done, de-nitrification was dominant

(Hill 1991; O'Driscoll & DeWalle 2010). When timber felling continues for a long time, the process of water loss from the surface of plants is interfered with; transpiration, will cause more runoff during the storms and flash floods. As the overflow moves downslopes, the nitrates are carried away (Vitousek & Melillo 1979; Reynolds & Edwards 1995; Creed *et al.*, 1996; Devito *et al.*, 2000; Gumiero *et al.*, 2011). In addition,soil properties, structure, and terrain of the land affect the loss of phosphorus.

In human planted forests, phosphorus and nitrates are added to the soil to enable the young trees to grow. It takes several years to regain soil fertility after harvesting. When forest harvesting occurs, there are no longer trees to absorb the water and hence, the other nutrients. Consequently, the essential nutrients such as nitrogen and phosphorous are eroded by water through streams and rivers. Such occurrences lead to dire consequences such as the loss of these crucial elements from the soil and hence leaving the ground acidic, a condition, which is harsh for the growth of plants. In addition of this, the lack of trees increases soil erosion leading to the degradation of soil as it loses essential nutrients. Forest harvesting also leads to a reduction of the natural habitat of various living organisms, which are important for the running of biogeochemical cycle.

CONCLUSIONS

Having analyzed the various biogeochemical cycles and their importance to the life of human beings and other living organisms, it is essential to note that forest harvesting threaten the continuity of these cycles. According to the literature review and result, the increased loss of organic matter and carbon content was predictable due to changes in the soil temperature, aeration, and impacts of treatment and site preparation. After harvesting, the site was mostly made up of carbon and CO_2 dissolved in soil water. These changes had an impact on the carbon cycle, and therefore possible changes in climate conditions (Schlesinger, 1991). The decomposition at high speed is linked to acidification of the soil, reduced nitrate, and affected hydrology.

It is important to protect the wetlands by maintaining the levels of nutrients in the soil at constant levels. The quality of water is an important factor in assessing the changes in the chemical composition of the soils. After 12 months, there was evidence of leaching. After 60 months after tree harvesting, nitrogen was released in the water within the soil. Nitrates were lost from the soil when it escaped in the form of nitrogen.

Forest harvesting is associated with changes in soil structure and chemical composition, vegetation, and the carbon, nitrogen, phosphorus, calcium, potassium cycles are affected. It is rational to reduce the disturbances in forests and wetlands through policy administration which may reduce the effects on soil and retain the biogeochemical status of wetlands. One of the methods is to use harvesting techniques that leave the branches, leaves, and the upper sections of trees in the harvested areas. This increases the amount of biomass for nutrient regeneration. In a conclusion, it is important to note that the more trees are cut down, the lower the quality of the environment and the ecosystem at large.

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